



# Development of AR Diorama Media to Enhance Reflective Thinking and Self-Regulation in Elementary IPAS

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Received: February 10, 2026

Revised: March 20, 2026

Accepted: April 25, 2026

Published: April 30, 2026

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DOI: [10.29303/jppipa.v12i4.14785](https://doi.org/10.29303/jppipa.v12i4.14785)

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**Abstract:** This study aims to develop and evaluate an Augmented Reality (AR)-based diorama learning media to enhance elementary students' reflective thinking and self-regulation in IPAS learning. This study employed a Research and Development (R&D) approach adapted from Borg and Gall, followed by a one-group pretest-posttest design to examine effectiveness. The participants were third-grade elementary students. Data were collected through expert validation sheets, practicality questionnaires, and reflective thinking and self-regulation test. Data analysis was conducted using descriptive statistics and normalized gain (N-gain). The results indicate that the developed media achieved very high validity ( $M = 3.76$ ) and practicality ( $M = 3.81$ ). The effectiveness test shows significant improvement in reflective thinking (N-gain = 0.68) and self-regulation (N-gain = 0.71), both in ranged from moderate to high categories. These study contributes by positioning that the integration of concrete diorama media with AR technology effectively promotes interactive, students-centered learning and supports the development of higher-order thinking skill and learner autonomy. This research contributes an empirically validated instructional media model elementary IPAS context that integrates physical and digital learning environments to enhance both cognitive and self-regulated learning outcomes in elementary IPAS.

**Keywords:** augmented reality, diorama media, reflective thinking, self-regulation, elementary IPAS

## Introduction

Elementary IPAS (Natural and Social Sciences) learning plays a crucial role in fostering higher-order thinking skills and learner autonomy from an early age (Bybee, R. W., 2013; Darling-Hammond et al., 2020). However, classroom practices remain largely teacher-centered and textbook-oriented, limiting students' opportunities to actively explore, analyze, and reflect on their learning experiences (Kependidikan et al., 2025; Trilling Bernie & Fadel Charles, 2009). As a result, students tend to become passive recipients of information and demonstrate limited ability to connect concepts with real-life contexts, which hinders the development of reflective thinking and self-regulation

skills (Kember et al., 2000; Siswa & Dasar, 2025; Zimmerman, 2002).

In the context of 21<sup>st</sup>-century education, students are expected to develop reflective thinking and self-regulation as essential higher-order skills (Ngatminiati et al., 2024; P. A., 2011; Transformasi et al., 2025). Reflective thinking involves analyzing experiences and evaluating learning processes, while self-regulation refers to learners' ability to plan, monitor, and evaluate their own learning (Aras et al., 2024; Caceres & Feigelson, n.d.; Sinensis & Firman, 2020). These skills are more effectively developed in student-centered learning environments supported by interactive media.

Dioramas offer concrete and contextual representations of IPAS concepts. However, their conventional use remains limited to static visual display

## How to Cite:

Adhimah, I., Setianingsih, R., & Rosmiati. (2026). Development of AR Diorama Media to Enhance Reflective Thinking and Self-Regulation in Elementary IPAS. *Jurnal Penelitian Pendidikan IPA*, 12(4), 713–720. <https://doi.org/10.29303/jppipa.v12i4.14785>

that lack interactivity. Augmented Reality (AR) technology has the potential to enhance learning through dynamic visualization and interactive exploration, enabling students to better understand abstract concepts (Aras et al., 2024; Satriawan & Rachmadtullah, 2024). However, previous studies on AR-based learning have primarily focused on improving engagement and conceptual understanding, while limited attention has been given to its role in fostering reflective thinking and self-regulation, particularly in elementary education contexts. Furthermore, the integration of concrete media such as dioramas with AR technology as a unified, process-oriented learning tool remains underexplored.

Although previous studies have demonstrated the effectiveness of AR in improving engagement and conceptual understanding, limited studies explicitly examine its role as a metacognitive scaffold for enhancing reflective thinking and self-regulation, particularly in elementary education context (Panadero, 2017; Radianti et al., 2020).

Therefore, this study addresses this gap by developing an AR-based diorama that integrates concrete representation, interactive visualization, and reflective scaffolding to support both cognitive and metacognitive learning processes. The novelty of this study lies in the design of hybrid instructional medium that not only support conceptual understanding but also explicitly enhances students' reflective thinking and self-regulation within an elementary IPAS learning context.

**Method**

*Research Design*

This study employed a Research and Development (R&D) approach using a modified Borg and Gall model, simplified into four main stages to ensure practical implementation while maintaining a systematic development process (Aisiah, 2016; Borg & Gall, 2003; Setyosari, 2016). The four stage included: (1) Preliminary Phase, (2) Planning and Development Phase, (3) Validation, Testing, and Revision Phase, and (4) Product Implementation and Effectiveness Testing Phase.

In the Preliminary Phase, classroom observations and structured interview with IPAS teachers at SDN Kepuhkiriman 1 were conducted to identify problems related to students' reflective thinking and self-regulation (Kependidikan et al., 2025; Materi et al., 2025; Panadero, 2017; Pendidikan et al., 2025). A literature review was also carried out to establish the theoretical foundation for media development.. In the Planning & Development Phase, learning objectives were formulated, AR content and physical diorama models were designed, and supporting instructional materials

including student worksheets and reflective prompt were developed.

In the Validation, Testing and Revision Phase, the developed media was evaluated by content and media experts to determine its validity. A limited trial was conducted with a small group (n = 10) to assess practicality and usability, followed by revision based on expert and user feedback. In the final phase, the revised product was implemented with a larger group (n = 25) using a one-group pretest-posttest design to evaluate its effectiveness in improving students' reflective thinking and self-regulation.



**Figure 1.** Borg & Gall Development Flowchart (Source : rarasaning <https://repository.upi.edu/32900/>)

*Participants*

The participants were third-grade students at SDN Kepuhkiriman 1 Waru Sidoarjo. A limited trial involved 10 students, while the field trial involved 25 students. The sampling technique used was purposive sampling, with criteria including students enrolled in Grade III IPAS and taught by teachers who participated in the preliminary study phase.

*Data Collecting Techniques*

- Data were collected three main instruments :
- (1) expert validation sheets assessing content, design, and technical aspects of the media;
  - (2) teacher and student response questionnaires to evaluate practicality; and

(3) pretest and posttest instrument measuring reflective thinking and self-regulation skills.

Content validity was established through expert judgment, while instrument reliability was analyzed using Cronbach's alpha coefficient. The reliability results indicated that all instruments met the acceptable criteria ( $\alpha \geq 0.70$ ), confirming their consistency for data collection (Dasar, 2025; Distrik, 2022; Materi et al., 2025; Ragil et al., 2023).

*Data Analysis*

Data analysis was conducted using descriptive and quantitative. Validation data were analyzed using mean scores and converted into validity categories (very valid, valid, less valid, and invalid) (Rosita et al., 2025). Questionnaire data were analyzed using percentage scores to determine the level of practicality.

The effectiveness of the developed media was evaluated using a one-group pretest-posttest design, which allows measuring learning gains before and after the intervention. The improvement in students' reflective thinking and self-regulation was analyzed using the normalized gain (N-gain) formula (Formula 1).

$$g = \frac{(Posttest - Pretest)}{(Maximum Score - Pretest)} \quad (1)$$

The N-gain scores were interpreted into three categories: high ( $g \geq 0.70$ ), moderate ( $0.30 \leq g < 0.70$ ), and low ( $g < 0.30$ ). This analysis was used to determine the effectiveness level of the developed media in improving students' learning outcomes.

**Result and Discussion**

*Preliminary Study Phase*

The preliminary findings indicate that IPAS learning in Grade III at SDN Kepuhkiriman 1 Waru Sidoarjo remains predominantly teacher-centered, characterized by lecture-based instruction and textbook dependency. This condition limits students' active engagement, resulting in passive learning behavior and minimal opportunities for exploration, reasoning, and reflection. Consequently, students demonstrate difficulties in expressing conceptual understanding, explaining reasoning, and connecting learning with real-life contexts.

From a media perspective, instructional tools are still limited to static and two dimensional representations. Existing diorama function merely as visual displays without interactive elements that could stimulate deeper cognitive engagement. This limitation restrict students' ability to analyze relationships between concepts and reflect on learning experiences.

Furthermore, students' reflective thinking and self-regulation skills were found to be underdeveloped. Students showed limited ability to plan, monitor, and evaluate their learning processes, indicating a high dependence on teacher guidance. These findings confirm a gap between the objectives IPAS learning which emphasize higher order thinking and learner autonomy and actual classroom practices.

These results are consistent with recent studies highlighting that teacher-centered instruction and limited use of interactive media hinder the development of higher-order thinking skill and self-regulated learning (Darling-Hammond et al., 2020; Panadero, 2017). Therefore, the development of interactive and technology-intergrated learning media is necessary to support more meaningful and student-centered learning.

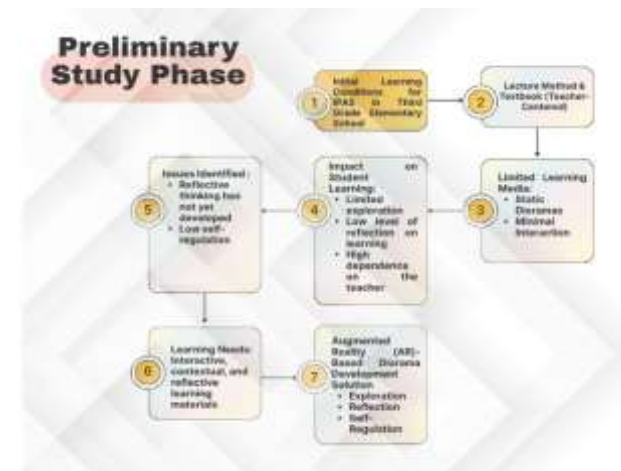


Figure 2. Preliminary Study Phase

*Planning and Development Phase*

Based on the identified needs, the AR-based diorama media was designed to integrate concrete and digital learning experiences. The development process emphasized contextual IPAS content, inquiry-based learning activities, and reflective prompts to facilitate students' cognitive and metacognitive processes.

The integration of physical diorama with AR technology allows students to observe real objects while simultaneously accessing dynamic visualizations of abstract processes. This design aligns with constructivist learning principles, which emphasize active knowledge construction through interaction with learning environments (Çeken & Taşkın, 2022).

In addition, the inclusion of reflective questions and structured learning activities positions the media not only as a visual aid but also as a metacognitive scaffold. Previous studies have shown that embedding reflective prompts in instructional design significantly enhances students' ability to regulate their learning and evaluate their understanding (Zimmerman, 2002).



Figure 3. Design of Learning Media Development

Validation, Trial, and Revision Phase

1. Expert Validation

The validation results indicate that the developed AR-based diorama media achieved a very high level of validity ( $M = 3.76$ ), confirming its alignment with curriculum content, instructional design, and students characteristics. High scores in interactivity and support for reflective thinking and self-regulation suggest that the media design successfully integrates cognitive and metacognitive dimensions.

This finding reinforces previous research emphasizing that well-designed multimedia learning environments can enhance both conceptual understanding and higher-order thinking skills (Delgado-kloos, 2018)

Table 1. Expert Validation Results of AR Diorama Media

No	Assessed Aspect	Validator 1	Validator 2
1	Alignment of material with Grade III IPAS curriculum	3.75	3.62
2	Accuracy and depth of IPAS concepts	3.40	3.70
3	Suitability of media for elementary students' characteristics	4.00	3.63
4	Visual appearance of the diorama and AR content	3.85	3.50
5	Interactivity and ease of media use	3.78	4.00
6	Media support for reflective thinking	3.73	3.72
7	Media support for self-regulation	3.77	3.80
Average		3.75	3.71
Percentage		93.80%	92.80%
Average Percentage			93.30%

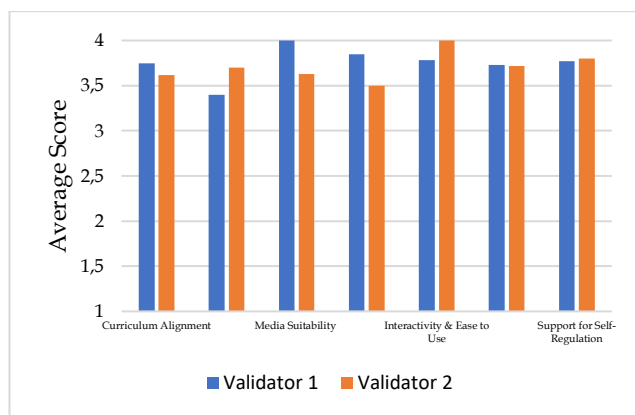


Figure 4. Validation Results of AR Diorama Media

2. Practicality (Limited Trial)

The limited trial results show that the media is highly practical ( $M = 3.81$ ), indicating that it is easy to use, attractive, and engaging for students. High levels of student engagement suggest that AR-based

visualization effectively captures learners' attention and promotes active participation.

These results are consistent with recent studies reporting that AR technology enhances motivation and engagement through immersive and interactive learning experiences (Radianti et al., 2020).

Table 2. Media Practicality Test Results (Limited Trial)

No	Practicality Aspect	Mean Score	Category
1	Ease of media use	3.80	Very Practical
2	Clarity of usage instructions	3.75	Very Practical
3	Attractiveness of media appearance	3.85	Very Practical
4	Student engagement in learning	3.82	Very Practical
Average		3.81	Very Practical

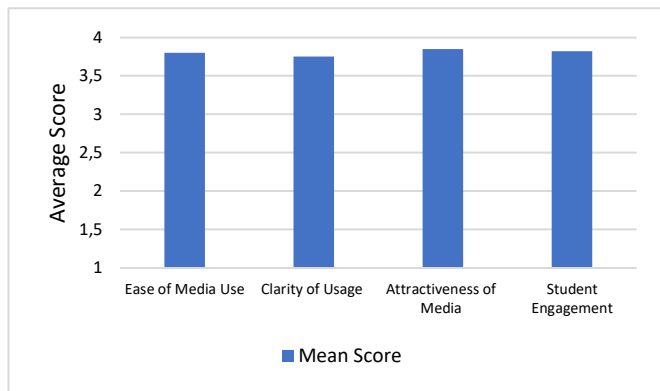


Figure 5. Media Practicality Test Results

3. Product Revision

Revisions focused on improving usability, including simplifying instruction, enhancing visual clarity, and strengthening reflective prompts. These improvements highlight the importance of iterative design in educational R&D to ensure both usability and pedagogical effectiveness.

Importantly, the enhancement of reflective question strengthens the role of media as a metacognitive tool, which is critical for fostering reflective thinking and self-regulation (Education, 2023; Kebaetse et al., 2023)

Table 3. Revisions of AR Diorama Media

No	Feedback	Revision Action
1	Usage instructions need to be simplified	Simplified instructional language
2	AR text size needs to be clearer	Adjusted text size and contrast
3	Reflective questions need to be emphasized	Added reflective prompting statements
4	AR navigation needs to be more responsive	Improved AR display settings

4. Effectiveness Test

The effectiveness test results indicate meaningful improvements in students' reflective thinking (N-gain = 0.68) and self-regulation (N-gain = 0.71). these findings suggest that the AR-based diorama media is effective in supporting both cognitive and metacognitive learning outcomes.

The improvement in reflective thinking indicates that students were able to analyze and evaluate their learning experiences more effectively. Meanwhile, this increase in self-regulation suggests that students developed greater autonomy in managing their learning processes.

These finding align with recent research demonstrating that AR-supported learning environment can enhance higher-order thinking and self-regulated learning by providing interactive and reflective learning experiences (Radianti et al., 2020).

Table 4. Effectiveness Test Results of AR Diorama Media

Measured Aspect	Mean Pretest	Mean Posttest	N-gain	Category
Reflective thinking	56	86	0.68	Moderate-High
Self-regulation	58	88	0.71	High

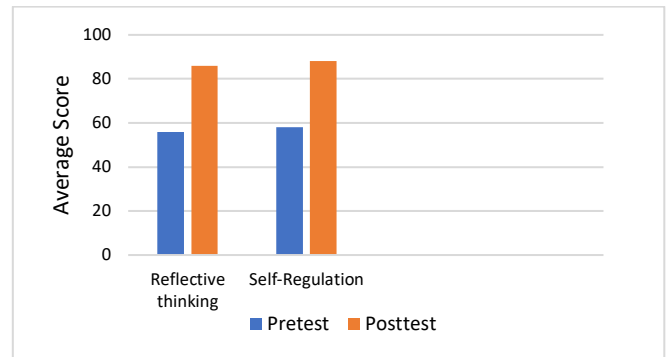


Figure 6. Effectiveness Test Results of AR Diorama Media

5. Product Outcome and Development Phase

The final product represents an integration of physical and digital learning environments, combining concrete diorama models with AR-based visualization. This hybrid approach provides a multimodal learning experience that supports both conceptual understanding and metacognitive skill development.

Unlike previous studies that primarily focus on engagement or conceptual gains, this study demonstrates that AR-based media can also function as a tool for developing reflective thinking and self-regulation. This highlight the potential of AR not only as a visualization technology but also as a pedagogical medium for fostering learner autonomy.

From a theoretical perspective, the findings support constructivist and metacognitive learning theories, emphasizing the role of interactive and reflective learning environments. From a practical perspective, the developed media offers an effective and feasible solution for improving IPAS learning in elementary schools.



Figure 7. Product Outcome and Development by Assemblr Edu

The preliminary findings reveal a persistent gap between the intended goals of IPAS learning—namely fostering higher-order thinking and learner autonomy and actual classroom practices, which remain predominantly teacher-centered. This instructional pattern limits opportunities for students to actively construct knowledge, resulting in low levels of reflective thinking and self-regulation. These findings are consistent with recent studies indicating that teacher-dominated instruction tends to suppress students' metacognitive development and independent learning skill (Darling-Hammond et al., 2020; Panadero, 2017).

From a media perspective, the reliance on static instructional tools, including conventional dioramas, restricts cognitive engagement to surface level learning. Prior research has shown that passive visual media are insufficient to support deep conceptual understanding and higher-order thinking processes (Radianti et al., 2021). Therefore, the limitation is not merely technological but pedagogical, as the media used do not facilitate interaction, exploration, or reflection.

A key contribution of this study lies in demonstrating that the integration of physical dioramas with Augmented Reality (AR) can address this gap by transforming passive learning environment into interactive and reflective ones. Unlike previous studies that primarily emphasize engagement or conceptual understanding, this study provides evidence that AR-based media can simultaneously support reflective thinking and self-regulation. This indicates a shift in the function of AR from a visualization tool to a metacognitive learning scaffold (Ardiansyah, 2024; Rojas-Sánchez et al., 2023).

The planning and development process further highlights the importance of aligning media design with constructivist and metacognitive principles. The inclusion of contextual content, inquiry-based activities, and reflective prompts enables students to actively engage in observing, analyzing, and evaluating their learning experience. This supports recent findings that instructional design integrating reflection and interaction significantly enhances students' ability to regulate their learning processes (Panadero, 2017; Zimmerman, 2002).

The validation and practicality results confirm that the developed media is both pedagogically sound and feasible for classroom implementation. However, the critical insight is not merely that the media is "valid and practical", but that its design successfully integrates cognitive (conceptual understanding) and metacognitive (self-regulation and reflection) dimensions. This dual function is often overlooked in educational media development, which tends to prioritize content delivery over learning process facilitation.

The effectiveness results further strengthen this argument. The moderate to high N-gain scores indicate that the AR-based diorama media contributes to meaningful improvements in both reflective thinking and self-regulation. Importantly, these improvements suggest not only better learning outcomes but also a shift in students' learning behavior from passive reception toward active and self-directed learning. This finding aligns with recent studies highlighting that technology-enhanced learning environment can promote deeper cognitive engagement when combined with reflective and interactive elements (Ateş & Polat, 2025; Radianti et al., 2020).

From a theoretical perspective, this study reinforces the integration of constructivist learning theory and self-regulated learning theory, demonstrating that meaningful learning occurs when students are actively involved in both knowledge construction and self-monitoring processes. From a practical perspective, the study offers an empirically tested instructional model that integrates concrete and digital media to support both cognitive and metacognitive development in elementary IPAS learning.

Overall, the main contribution of this study lies in extending the role of AR in education from enhancing visualization to facilitating reflective and self-regulated learning. This positions AR-based diorama media as a strategic solution for addressing the limitations of conventional IPAS instruction and supporting the development of higher-order thinking skills and learner autonomy in elementary education.

## Conclusion

This study concludes that the Augmented Reality (AR)-based diorama learning media, developed through the Research and Development approach is empirically proven to be valid, practical, and effective for elementary IPAS learning. Expert validation confirms that the media meets high standards in terms of content accuracy, instructional design, and technical quality, while teacher and student responses indicate that the media is feasible, engaging, and easy to implement in classroom setting.

The effectiveness results demonstrate significant improvement in students' reflective thinking and self-regulation, as indicated by moderate to high N-gain scores. More importantly, these findings suggest a shift in students' learning behavior from passive recipients of information toward active and self-directed learners. The integration of physical diorama with AR technology not only enhances conceptual understanding but also functions as a metacognitive scaffold that supports students in planning, monitoring, and evaluating their own learning processes.

the main scientific contribution of this study lies in providing an empirically validated instructional model that integrates concrete and digital learning environments to simultaneously foster cognitive and metacognitive skills. Unlike most AR-based studies that focus primarily on engagement or conceptual gains, this study demonstrates the potential of AR-based media to support reflective thinking and self-regulated learning in a structured and measurable way, particularly in the context of elementary IPAS education.

From a practical perspective, this study offers clear implications for teachers. The AR-based diorama media can be used as an alternative instructional tool to facilitate student-centered learning, especially in implementing the principles of the Merdeka Curriculum. Teachers are encouraged to integrate reflective questioning and guided exploration when using the media to maximize its impact on students' higher-order thinking and learning autonomy.

For future research, it is recommended to conduct large-scale experimental studies involving control groups to strengthen causal evidence of effectiveness. In addition, further studies may explore the application of this media across different grade levels, subject areas, and learning contexts, as well as its long-term impact on students' metacognitive development and academic performance.

#### Acknowledgments

The authors sincerely thank to Universitas PGRI Adi Buana Surabaya, the lecturers, the principal, teachers, and students of SDN Kepuhkiriman 1 for their trust, cooperation, and active participation throughout this study. Special appreciation is extended to the IPAS teachers for their openness, insights, and continuous support during the research process. The authors are also grateful to the expert validators for their valuable feedback, which significantly improved the quality of the developed learning media. This research was made possible through the collective support and contributions of all parties involved.

#### Author Contributions

Conceptualization, **I.A.** and **R.S.**; methodology, **I.A.**; software, **I.A.**; validation, **I.A.**, **R.S.**, and **R.**; formal analysis, **I.A.**; investigation, **I.A.**; resources, **I.A.**; data curation, **I.A.**; writing—original draft preparation, **I.A.**; writing—review and editing, **I.A.** and **R.S.**; visualization, **I.A.**; supervision, **R.S.** and **R.**; project administration, **I.A.**; funding acquisition, **R.S.**. All authors have read and agreed to the published version of the manuscript.

#### Funding

This research received no external funding. The Article Processing Charge (APC) was not funded by any external funding agency.

#### Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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